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Article (Accepted Version)

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Abstract

We develop a lean readiness framework and an assessment methodology to quantify the readiness of healthcare institutions for implementing lean. We use stakeholder theory and work with a lean implementation team responsible for process improvement in a healthcare group to develop the framework. The framework uses fuzzy based input derived from the stakeholders of the healthcare institution to generate an overall ranking through ideal solution technique. The assessment method derives input from the readiness scores shared by various stakeholders. The ranking suggests future improvement areas to prepare the healthcare institution for a lean implementation project. We provide an alternative perspective of assessing the lean readiness of healthcare institutions before beginning a lean implementation project for both researchers and practitioners. Our research is the first to develop a lean readiness framework for healthcare institutions and demonstrate it using an assessment technique.

Keywords: Lean Operations, Readiness, Assessment, Fuzzy Logic, Healthcare Institution, Service.

1. Introduction

Recently, lean has seen numerous applications in healthcare institutions, which include hospitals and clinics, physician practices, nursing homes, and health maintenance organizations (e.g. Poksinska, 2010; Mazzocato et al., 2010; Hicks et al., 2015; Narayanamurthy and Gurumurthy, 2017). Lean has been used to remove duplicate processes and unnecessary procedures such as recording patient details in multiple places, patients being moved to multiple wards, excessive waiting by patients for doctors and consultants, and uncoordinated discharge processes resulting in a longer

length of stay than necessary (Radnor, 2011). According to Radnor et al. (2012), 35% of process improvement publications are in the context of healthcare. Therefore, lean as a tool has a huge potential to drive healthcare reforms.

Despite the wide application of lean in healthcare, the success rate has remained very low. Past experiences of lean implementation projects in healthcare institutions show that failure rates range between 50 percent and 95 percent (Thelen, 2016). We identified the following three major reasons from literature for the large proportion of failures:

Absence of adaptation - Metrics on process boundaries, roles and responsibilities, operational processes, customer expectations, demand and variation, as well as strategy are subjective and perceptual in service organizations (Radnor, 2011). Especially for knowledge-intensive service sectors such as healthcare, the reasons for the introduction of lean practices focusing on improving the value, process and flow are not clear (Radnor and Bucci, 2007). This lack of adaptation of the lean concept to service contexts such as healthcare increases the probability of failure.

Lack of readiness - Articles published in literature have discussed the importance of readiness aspects and have agreed that being ready for lean implementation is a prerequisite to be successful in the roll out of lean projects (e.g. Gurumurthy et al., 2013; Garza-Reyes et al., 2015), especially in the health care sector (e.g. Radnor, 2011; Al-Balushi et al., 2014). Lean sensei and consultants attribute the failure to already existing inefficiencies in the management systems rather than concerns brought about by introducing the lean elements to the firm (Wilson, 2013). For instance, the lack of knowledge about the lean concept, the lack of a system to resolve employee issues, or the absence of appropriate training systems, etc. have been found to be among the major sources of lean implementation failures.

Even though lean implementation can start at the fringe of an organization and grow organically if successful (bottom-up approach), a decision to adopt lean is an organization wide (i.e. healthcare institution wide) initiative strategically taken by the top management (top-down approach). Hines et al. (2008) and Bhasin (2012) affirm that any strategy including lean, regardless of its strengths, will not be accepted if it is outside an organization's culture. As adopting lean is highly resource intensive (e.g. time, labor, money, etc.), the top management of a healthcare institution wants to do it right the first time (a practice in lean) by investing sufficiently in becoming ready for a lean implementation project through putting an appropriate culture and infrastructure in place. Supporting this claim, literature has also confirmed that the lack of corporate culture and change management represent a fundamental issue causing failure in lean implementation projects (Saurin et al., 2011) and has highlighted the importance of readiness for a successful lean implementation.

Lack of systemic approach - Although lean implementation is increasingly prevalent in healthcare institutions, the literature suggests that healthcare organizations implementing lean are short-term focused and take the piece-meal approach of deploying only simple tools and techniques for solving selected problems (De Souza 2009). No healthcare institution has fully institutionalized lean to the level of Toyota on the ability to design and improve the work, share the resulting knowledge from the work, and develop people for work (Spear, 2005, pp. 91; Losonci et al., 2011).

Our research addresses the above-listed reasons for the failure of lean implementation projects in healthcare institutions. This research is imperative as it is necessary to not only adapt the lean philosophy to the healthcare context by capturing the intricacies and by acknowledging the key differences, but also to assess the readiness of the healthcare institutions to guide them along the lean journey. A lean journey comprises of three different stages, namely readiness (pre-implementation stage), lean practices (implementation stage), and lean performance (post-

implementation stage) (Narayanamurthy and Gurumurthy, 2016). Our research is a step towards the objective of addressing the identified common reasons for the failure of lean projects by contributing to the readiness stage (pre-implementation stage) of a lean journey. Narayanamurthy and Gurumurthy (2016) have carried out a review of lean assessment techniques and called for future studies to focus on readiness (pre-implementation) assessments in lean projects implemented across sectors such as healthcare, software development, etc. Our study is also a response to this call for research. In sum, we develop a stakeholder-based healthcare institution readiness instrument and append it with a mathematical model for assisting process improvement practitioners of healthcare institutions.

Organizational readiness, in general, is defined as the ability of the organization to undergo a smooth transformation to respond to the changing needs and expectations of its internal and external environment. Readiness of the organization to undergo change is primarily decided by the change commitment and change efficacy of an organization's members to implement the announced organizational change (Weiner et al., 2008). Borrowing from change management literature, readiness for change is seen as 'the cognitive perspective to the behaviours of either resistance to, or support for, a change effort (Armenakis et al. 1993: 681-682). Such perceptions can facilitate or undermine the effectiveness of a change intervention/initiative (Armenakis et al. 1993; Eby et al., 2000). Organization theory literature has seen lean implementation as a change agent as it can completely change the way value delivery is perceived and achieved (e.g. Piercy & Rich, 2009; Tsasis & Bruce-Barrett, 2008). For instance, to achieve the objective of a smooth lean implementation, a healthcare institution needs to consider aspects such as awareness to realize the requirement for process improvements, development of an improvement strategy with a roll out plan, a culture to focus on customer requirements, a systemic processes view, the practice of using data to drive improvements, engaged staff with appropriate training, a committed leadership team, and knowledge of demand, capacity, and variation (Radnor, 2010; Radnor, 2011). Therefore, in the context of lean

implementation, we define healthcare institution readiness as the healthcare institution's ability to smoothly imbibe the reengineering changes with least resistance from the stakeholders for the effective and sustainable use of the lean tools in order to achieve the targeted outcomes. Healthcare institution readiness can also be defined as the satisfactory attainment of prerequisites before proceeding with any re-engineering/improvement in a healthcare institution. For example, without understanding customer values and needs it would not be possible to develop a value stream map. Similarly, without understanding the variation in data used for visual management charts, it would be meaningless and even hard to interpret the available information (Abdulmalek and Rajgopal, 2007; Radnor and Bucci, 2007). Any preparation that is done before the actual lean rollout can be seen as becoming ready for the change. Actual lean implementation begins when the healthcare institution starts directly attacking the inefficiencies and wastes in a value stream by following the five tenets of lean (Womack and Jones, 2009). This understanding helps in demarcating the boundary between readiness (pre-implementation) and rollout (implementation) stage.

The overarching research questions (RQ) that we try to answer in this study is as follows: *What are the prerequisites that a healthcare institution has to satisfy to become ready for implementing lean and how to measure the readiness of a healthcare institution using these prerequisites?* By answering these research questions, we are confident to achieve the following objectives:

(1) Identifying the readiness factors for healthcare institutions by comprehensively reviewing the lean implementation literature in healthcare institutions.

(2) Proposing a lean readiness framework for healthcare institutions based on the factors identified from the literature review.

(3) Developing a readiness instrument that provides a categorization of healthcare institutions based on their readiness level.

(4) Developing a mathematical model applying the lean readiness framework to assess the readiness level of a healthcare institution.

Thus, our research contributes to the healthcare literature in at least three ways. First, we introduce the importance of considering healthcare institution's readiness for successful lean implementation projects. In particular, we identify a set of readiness factors for implementing lean practices in healthcare institutions. Second, we develop a stakeholder-based lean readiness framework by grouping the identified readiness factors under six different stakeholders. Lean implementation in healthcare institutions literature clearly indicates that the implementation of each lean practice depends on a specific stakeholder of the healthcare institution. Hence evaluating the readiness of those stakeholders is a paramount prerequisite for lean implementation. Finally, we develop a single numeric readiness index for healthcare institutions to estimate their readiness level.

2. Literature review

Our literature review primarily focusses on the implementation of lean in healthcare institutions and draws insights on the readiness aspects of lean implementation.

2.1. Lean implementation in healthcare institutions

We carried out a detailed review of over 130 papers adopting a case study research methodology to document the experience of implementing lean in various healthcare institutions. Table 1 and Table 2 show a snapshot of the literature review on implementation of lean in healthcare institutions. Table 1 captures the name of the healthcare institution studied, research question addressed, and results obtained. Table 2 captures the lean practices

and performance measures documented in the literature. The review showed that close to 60% of the literature have documented the lean implementation experiences of healthcare institutions in the USA and UK. Emergency, nursing, cardiac, and pharmacy departments have seen widespread implementations of lean. The review also revealed that over 85% of the literature discussed lean implementation in multispecialty hospitals. A common observation across all the studies was that lean implementation procedures, lean practices, and performance measures adopted in healthcare institutions were contextual and varied from case to case. For instance, King et al. (2006) used a process mapping tool to group patients together for minimizing complex queuing in the emergency department, whereas Jimmerson et al. (2005) adapted Value Stream Maps (VSM) and problem-solving A3 report tools to improve patient or information flow issues across multiple departments. However, lean implementation in the manufacturing sector has largely adopted a standard procedure fitting with the five tenets of lean proposed by Womack and Jones (2009). A possible explanation for these variations in the healthcare institution context could be the problem-driven lean adoption approach. Most of the healthcare institutions analyzed in the literature review used lean as a toolbox to solve some immediate problems faced. Studies have indicated the importance of proper orientation for getting ready before rolling out lean projects (Narayanamurthy et al., 2017). Based on the evaluation of the research questions addressed and the results obtained in the reviewed papers (listed in Table 1), we can conclude that no framework or assessment tool for the lean readiness of healthcare institutions exist.

"Insert Table 1 & Table 2 here"

As part of our review, we also captured the lean practices and performance measures documented in the literature (listed in Table 2). A key observation was that these practices and performance measures were primarily targeting specific stakeholders of healthcare institutions. Building on to this observation, we clustered the practices and performance measures under different stakeholders namely the leadership and executive

team, the lean sensei and team, the frontline management team (employees of the healthcare institution), the patients and other customer groups, supplier groups, etc. Overall, the implementation of these lean practices and performance measures were found to be driven by the stakeholders of the healthcare institution. This triggered the motivation to develop a lean readiness framework based on stakeholder theory (Harrison and Wicks, 2013) as discussed in detail in section 3 of this paper.

In addition, we attempted to identify implicitly mentioned readiness factors from the review of lean implementation projects in the healthcare literature. Very few studies have discussed the readiness aspects explicitly confirming the importance of pursuing future studies in the readiness domain (e.g. Radnor, 2011; Al-Balushi et al., 2014). Few studies in the general lean literature have also documented the aspects of readiness (e.g. Gurumurthy et al., 2013; Garza-Reyes et al., 2015). In Table 3, we present a snapshot list of readiness factors identified from the reviewed studies. In section 3, we use inputs from this table to develop a stakeholder-based lean readiness framework. In the detailed review carried out by Narayanamurthy and Gurumurthy (2016) on lean assessment, they found hardly any indication of lean assessment techniques to evaluate the readiness of an organization.

"Insert Table 3 here"

2.2 Research gaps

As the success or failure of a lean project heavily depends on the healthcare institution's proactive readiness, it becomes imperative to understand this aspect in the context of lean implementation by developing a methodology for the assessment of the readiness of healthcare institutions. Our review of literature presented above clearly revealed the following gaps:

1) *The absence of a lean readiness framework that can be used by practitioners for checking if healthcare institutions are sufficiently ready to begin their lean journey.*
2) *A lack of discussion on the importance of stakeholders in making the healthcare institution ready for their lean journey.*
3) *The unavailability of methodology for systematically assessing the readiness of a healthcare institution and quantifying the level of readiness of different stakeholders.*

Our research addresses the above-listed gaps to assist healthcare practitioners in diagnosing their healthcare institution's lean readiness.

3. Stakeholder-based lean readiness framework for healthcare institutions

Our literature review on the implementation of lean in healthcare institutions (Table 1 to Table 3) showed that the deployment of lean practices and performance measures depends heavily on the involved stakeholders of the healthcare institution. For instance, implementing "5S", a practice for housekeeping, has to be carried out by employees and in particular, the front-line employees such as physicians, nurses, lab technicians, etc. Hence, the "employee" stakeholder has to be trained and made ready on this lean practice for its successful implementation. Similarly, all other lean practices can be mapped to a prime stakeholder who plays a predominant role in the successful implementation. Therefore, we develop a stakeholder-based lean readiness framework (Harrison and Wicks, 2013), to check the readiness of the different stakeholders.

Phillips (2003) defines a firm's legitimate (or normative) stakeholders to be those to whom the firm owes an obligation based on their participation in the cooperative scheme that constitutes the organization and makes it a going concern. It includes stakeholders external to the firm namely customers, communities in which the firm operates, and suppliers in the list of legitimate stakeholders. In addition to these, internal

stakeholders include the executive team and different employee groups (Harrison and Wicks, 2013). Stakeholder theory has been widely used to understand how efficiently and effectively different stakeholders (both internal and external) can be cooperatively involved to achieve high performances along the triple bottom line dimensions of an organization and ensure to keep all the stakeholders happy (Freeman et al. 2007). Stakeholder theory's key objective is to create a higher level of well-being for the stakeholders involved in a system of value creation led by the firm. The implementation and management of any change such as lean at the firm impacts its stakeholders and value creation processes. Ensuring the stakeholder's readiness for lean implementation enhances the well supported positive relationship between stakeholder-oriented management and firm performance (Choi & Wang, 2009; Freeman et al., 2010) and also between lean implementation and operational performance (Yang et al., 2011; Khanchanapong et al., 2014; Qi et al., 2017). As a result, stakeholder theory provides a suitable perspective to study the readiness of a firm to implement lean as conceptualized in Table 4.

Our proposed framework is unique to the context of healthcare. For instance, the elements (also stakeholders) such as *frontline management team* and *patients and other customer groups* are uniquely operationalized to healthcare institutions and would be absent in the context of manufacturing. Frontline management teams of healthcare institutions comprise of physicians, nurses, and other medical staffs while the frontline management teams in a manufacturing firm would comprise of shop floor employees, supervisors, foreman, line managers, and team leaders. Similarly, patients and other customer groups such as patient's close family, visitors of patient, laboratories, etc. of healthcare institutions are very different from the customers of manufacturing firms. Even though stakeholder theory is applicable to several other industries, the operationalization of the theory and associated elements and sub-elements has to be restated by anchoring to the industry's context. We believe this to be also the

strength of the framework proposed in our research as it can explain the readiness of firms operating in different industry sectors by only adapting the operationalization of the elements and sub-elements.

We describe each of the elements and list the associated sub-elements of our lean readiness framework below. Refer to **Appendix I** for the detailed description of the sub-elements within an element and the rationale for considering it.

"Insert Table 4 here"

3.1. Leadership and executive team

The leadership and executive team generally ideate the need for lean in their healthcare institution and visualize the journey they will take to reach the aspired future state. Hence, they need to be prepared for what it will take to succeed in this journey. Their lack of readiness will introduce unexpected challenges and resource constraints that will push them to drop the lean initiative taken up at their healthcare institution. The leadership and executive team can prepare to become ready by addressing the following sub-elements: strategic agenda alignment, organic structure and open culture, systems approach, instituting lean positions, lean know-how, job security, and top management commitment.

The leadership and executive team has to *align their healthcare institution's strategic agenda* (vision and mission) in line with the objective of implementing lean. To align their strategy, the top executive team has to be trained first on the basics of lean and have to concretize their *lean know-how* to understand what can be realistically expected from implementing lean and how important their role is in achieving the expectations. This will also signal to the physicians, nurses, and other medical staffs of their healthcare institution that the *top management* is *committed* and serious about this transformation. To achieve the *lean know-how*, leadership and executive team have to approach consultants of lean in healthcare

who are also known as lean sensei. The leadership and executive team has to *institutionalize dedicated lean positions* (such as lean sensei, lean champions, etc.) with the responsibility of introducing lean concepts to the employees of the healthcare institution and support them along the lean journey. The readiness of the leadership and executive team can be determined by few other aspects such as the organization structure (mechanistic or *organic*) and employee *job security* (no fire policy). The leadership and executive team of the healthcare institution can be considered better ready for lean implementation if they have truly adopted *organic structure with open culture* of making all the employees feel important and there is *no fear of termination* for cutting costs or for revealing the inefficiencies in the process. Finally, the maturity in readiness of the leadership and executive team is determined by its ability to adopt *systems approach* in solving problems and taking decisions.

3.2. Frontline management team

Frontline management teams including the physicians, nurses, and other medical staffs in a healthcare institution play a very significant role in implementing a variety of lean practices. Even though it is the leadership and executive team which decides on rolling out lean, it is the frontline management team that implements lean in the actual operations of a healthcare institution. The readiness of a frontline management team can be achieved by addressing the following sub-elements: customized hands-on training, knowledge of the existing systems, multi-skilled, team-working culture, respect for peers and subordinates, least resistance to change, and employee involvement and engagement.

Customized hands-on training has to be provided to all physicians, nurse, and other medical staffs on the prerequisites and basic concepts of lean through pilot projects and demonstrations to help them understand what lean transformation looks like. The entire frontline management team has to be *knowledgeable on the existing systems*. They should have a full understanding of all the activities and functional areas within and

across the process and be capable of proposing suggestions for redesigns in future. Physicians, nurses, and other medical staffs have to be trained and experienced with *multiple skills* to work in different positions within and across processes in the healthcare institution. They have to be experienced in *working in teams* with an objective to improve the patient experience and overall team performance. *Respect for peers and subordinates* between different departments and across employee levels has to be inculcated. Frontline management team is considered to be ready when they *do not exhibit resistance to change* and develop the ability to quickly learn/unlearn from the experience to improve the efficiency of the processes. The meaningful *involvement and engagement of physician, nurse, and other medical staff* including healthcare institution's senior doctors have to be inculcated. Nurses and other medical staffs have to embrace ownership of the processes to identify and recommend improvements in their day-to-day job and associated processes.

3.3. Lean sensei and team

The lean sensei and team represent the expert committee that will plan, guide, and coordinate the lean journey of the healthcare institution by acting as a bridge between leadership and executive team's expectations and frontline management team's efforts. This team has to be visualized by the leadership and executive team well before beginning the lean journey and have to be brought onboard at the earliest. Usually, the lean sensei and team is a composition of lean consultants (expertise in lean philosophy) and proactive frontline management team members (expertise in healthcare institution's "as-is" status). The readiness of the lean sensei and team can be evaluated using the following sub-elements: expertise of sensei and team, lean journey roadmap, comfort with the team responsible for implementing lean, traveling together attitude, and process-learning metrics.

A lean sensei and team should have *expertise in lean implementation* for successfully guiding the healthcare institution in its lean journey. The lean sensei has to form the team such that the members complement each other's expertise and holistically have the adequate expertise to start the lean journey. Complete details on how the lean implementation will be rolled out in the healthcare institution called as *lean journey roadmap* need to be planned in detail by the lean sensei and team. *Comfort with the lean team* captures how comfortable are the frontline management team in interfacing with the lean sensei and team. Lean sensei has to create a climate of encouragement and urge the frontline management team to work in hands with lean sensei and team for improving the experience of patients. Lean sensei and team have to impart *traveling together attitude* among all the stakeholders of the healthcare institution to synchronize all their viewpoints and ensure that everyone is on the same page for the lean journey to be started. Lean sensei and team have to identify *process-learning metrics* that have to be relevant, recognizable, and easy to implement before proceeding with the lean journey.

3.4. Patients and other customer groups

Patients and other customer groups such as patient's close family, visitors of patient, laboratories, neighboring societies, etc. will be impacted by a lean transformation. Customer groups can be either internal (inpatient) or external (outpatient) to the healthcare institution. Moreover, a lean transformation of a healthcare institution is pursued to add value defined by the customers. Hence, healthcare institutions have to understand the aspects related to customers before proceeding with the lean implementation and inform patients about the planned lean transformation in the future and to involve them in the process. The readiness for this stakeholder group can be evaluated through the following sub-elements: knowledge of customer groups, patient respect, involvement and engagement, and patient's knowledge of "end to end" process pathway.

Knowledge of both internal and external customer groups is essential to rightly define the value for these customer groups such that they can be linked to different improvement initiatives that will be taken up in the future. *Respecting, involving and engaging patients and other customer groups* in the treatment process is an essential readiness aspect for succeeding along a lean journey. *Patient's knowledge of "end to end" process pathway* indicates how much the healthcare institution has involved and engaged the patient and has informed them about their processes.

3.5. Supplier groups

Supplier groups play a very important role in successfully implementing lean projects in healthcare institutions as they can potentially increase or decrease the existing wastes. Supplier groups have to be ready for a lean implementation project, which can be measured by understanding the following sub-elements: supplier collaboration and partnership, supplier involvement and alignment, and supplier service quality.

Supplier collaboration and partnership increase the readiness for lean implementation at healthcare institutions as it increases the ability to monitor and share real time information. *Supplier involvement and alignment* can be achieved by aligning the supplier's vision and mission to the healthcare institution. High *supplier service quality* achievement by delivering consistently good quality product and services is also an important characteristic of a supplier who is ready for lean implementation.

3.6. Healthcare institution attributes

Healthcare institution attributes are those characteristics of healthcare institution (similar to focal organization in a supply chain context) which needs to be made favorable for lean implementation. This involves primarily fixed resource investments that are independent of lean

implementation. The readiness of the attributes related to the healthcare institution can be evaluated using the following sub-elements: data measurement system, capacity and demand matching efforts, past change experiences, and patient and employee safety.

Accurate *data measurement system* has to be in place to monitor the processes in the healthcare institution. Data compatibility across processes and departments has to be ensured before beginning the lean journey. *Capacity and demand matching efforts* have to be taken by the healthcare institution to optimally utilize its fixed and variable resources to achieve maximum efficiency. *Past change experiences* of the healthcare institution with different initiatives other than lean needs to be relooked. Learnings from the past experience need to be incorporated in the current initiative to avoid repetition of mistakes. Ensuring *patient and employee safety* is a key prerequisite before any change initiative. A safe environment and conducive conditions that can prevent injuries and strain on both patients and frontline management team are mandatory for a healthcare institution.

The lean readiness framework described above is used to assess the lean readiness of a healthcare institution using fuzzy input based similarity to ideal solution assessment method.

4. A methodology for lean readiness assessment of healthcare institutions

Our stakeholder-based lean readiness framework developed in the previous section had been verified by brainstorming with the lean implementation team of a healthcare institution group. Subsequent to the verification, we used our lean readiness framework to collect data from a healthcare unit (within the healthcare institution group) which was planning to implement lean in near future.

4.1. Case organization

The case organization we studied in this research is part of a larger healthcare group, which comprises of multiple hospitals, primary care clinics, a home care, and a medical transportation center. The healthcare group is known for its excellence in family health and specialization, including primary, maternity, orthopedics and post-acute care. The entire healthcare group has over 7,500 employees and 850 physicians who are highly committed to deliver compassionate health care that puts the patient and their needs first. We submitted the proposal for assessing the readiness to implement lean at this healthcare institution to the lean sensei of the healthcare group. On reviewing the proposal and after discussing with us on the objectives of this study, the lean sensei proposed a primary care clinic within their healthcare group as an ideal candidate for our research. The lean sensei and his team were also interested to check how the proposed clinic performed in our readiness evaluation and what can they focus on to improve before beginning the actual implementation of lean. We visited the healthcare unit once every week for over three months. We first started by getting introduced to different stakeholders, followed by collecting data necessary for assessing the readiness, and finally interpreted the results obtained from the assessment. The lean sensei and his team of the healthcare group assisted in achieving the objectives during all the visits by connecting with physicians, nurses, and other medical staff of the healthcare unit.

4.2. Fuzzy input based readiness assessment method

Fuzzy technique helps in overcoming the “imprecise”, “vague”, “partial truth” and “multi-possibility” in responses. For instance, it takes into consideration the concept of partial truth, where in our study the truth-value can vary from “fully ready” to “not ready". Fuzzy sets were introduced by Zadeh (1965) to represent data and information processing non-statistical uncertainties. The fuzzy technique uses degrees of truth as a

mathematical model of vagueness and probability associated with it as a mathematical model of ignorance. In addition, this technique is capable of tolerating the blurred boundary in definitions and enables assessors to use linguistic terms to assess indicators in natural language expressions (Lin and Chen, 2004).

As the readiness for lean implementation in a healthcare institution is to be assessed, we expect the assessors to be not much aware of lean philosophy and readiness of all stakeholders of the institution for lean implementation. It is very likely that assessors provide variable answers when asked for how ready a particular stakeholder of the healthcare institution is. For instance, one assessor might find a particular stakeholder to be "somewhat ready", but second assessor can interpret the same stakeholder to be "almost ready". The fuzzy technique helps in such instances to arrive at a more appropriate truth by using the result of reasoning from such inexact, imprecise, and partial knowledge in which the sampled answers are mapped over a spectrum.

Based on the review carried out by Narayanamurthy and Gurumurthy (2016), lean assessment studies in services are scarce and almost non-existent in the context of healthcare institutions. Their review also showed that lean assessment studies in manufacturing context have used fuzzy techniques significantly apart from other methodologies such as Mahalanobis distance, data envelopment analysis, analytic network process, and value stream mapping to conduct the assessment. Among these methods, we selected the fuzzy technique for carrying out the assessment as it is close to realistic judgments and have been frequently prescribed in the manufacturing context but have not been put to use in the healthcare sector (Abbod et al., 2001). In this research, we develop Fuzzy Input Based Similarity to Ideal Solution Readiness Assessment Method by adopting the procedure proposed by Chen and Hwang (1992), Triantaphyllou and Lin (1996), Wang and Elhag, (2006), and Wang and Lee (2008) (Figure 1).

"Insert Figure 1 here"

We collected input fuzzy data for the assessment method from a physician, nurse, executive team member, member of the lean sensei team, and staff of the primary care clinic using the instrument shown in Table 5 and Table 6. We developed linguistic scale for the readiness evaluation by discussing with the members of lean sensei team. The linguistic scale we used for measuring the *Extent of Readiness* of sub-elements and *Importance Weight* of readiness elements and sub-elements is shown in Table 7. A snapshot of the final linguistic data collected by us on the *Extent of Readiness* and *Importance Weights* for LRF1 is shown in Table 8. Similarly, we collected data for all the remaining elements and sub-elements.

"Insert Table 5 to Table 8 here"

Based on the corresponding relation between the linguistic terms and fuzzy numbers as listed in Table 7, we approximated and averaged the linguistic terms of *Extent of Readiness* and *Importance Weight* using fuzzy numbers. Assume that a committee of *m* evaluators, i.e., E_t, t = 1, 2, ..., m, conduct the healthcare institution's readiness evaluation. Let F_j, j = 1, 2, . . ., n; be set of readiness factors within a particular stakeholder category which need to be evaluated for assessing the healthcare institution's readiness for implementing lean. Let $R_{tj} = (a_{jt}, b_{jt}, c_{jt})$ be the fuzzy numbers approximating the linguistic *Extent of Readiness* given to F_j by the assessor E_t, and let $W_{tj} = (x_{jt}, y_{jt}, z_{jt})$ be the fuzzy numbers approximating the linguistic *Importance Weight* assigned to F_j by the assessor E_t. Using the average fuzzy *Extent of Readiness* R_j and average fuzzy *Importance Weight* W_j, we calculated the aggregation of the opinions of experts as

$$R_j = (a_j, b_j, c_j) = (R_{j1\,(+)}\, R_{j2}\, (+) \ldots (+)\, R_{jm})/m \qquad (1)$$

$$W_j = (x_j, y_j, z_j) = (W_{j1\,(+)}\, W_{j2}\, (+) \ldots (+)\, W_{jm})/m \qquad (2)$$

For example, consider the conversion of *Extent of Readiness* and *Importance Weight* for the lean element 'LRF1.1' into fuzzy number as shown in Table 9. We obtained the Fuzzy average *Extent of Readiness* and *Importance Weight* in the last row of Table 9 by following the procedure shown in eq. (1) and (2). Similarly, we averaged the *Extent of Readiness* and *Importance Weight* fuzzy numbers for the elements and sub-elements in the lean readiness framework.

"Insert Table 9 here"

We computed the product of average fuzzy numbers of *Extent of Readiness* and *Importance Weight* of sub-elements to calculate the readiness level as shown in Table 10. We evaluated centroid score of readiness level to generate the readiness value of each of the sub-elements as shown in Table 10.

"Insert Table 10 here"

We computed the fuzzy *Extent of Readiness* for elements by applying equation 3 on sub-elements within an element of lean readiness framework (Kao and Liu, 2001). Let R_j and W_j (where j = 1, 2, . . ., n; and n is the number of sub-elements within an element) denote the average fuzzy *Extent of Readiness* and *Importance Weight* given to a sub-element 'j' within an element of lean readiness framework by the assessors. We computed the *Extent of readiness* of an element as

$$Extent\ of\ Readiness\ of\ an\ Element\ = \frac{\sum_{j=1}^{n}(Wj(.)Rj)}{\sum_{j=1}^{n} Wj} \qquad (3)$$

We computed the product of fuzzy numbers of *Extent of Readiness* (using equation 3) and *average Importance Weight* of elements to calculate the readiness level of elements as shown in Table 11. We evaluated the centroid score of readiness level to generate the readiness value of each of the elements as shown in Table 11.

"Insert Table 11 here"

Finally, we computed the overall Healthcare Institution Lean Readiness Index (HLRI) by applying equation 3 but at the element level. For computing HLRI, R_j and W_j (where j = 1, 2, . . ., n; and n is the number of elements in the lean readiness framework) denote the computed fuzzy *Extent of Readiness* and Average *Importance Weight* for element 'j' respectively. HLRI determines the aggregated extent of readiness attained by putting together all the stakeholders of the case organization. Our computation showed HLRI of the case organization as (4.797, 5.744, 6.703) with centroid score of 5.75, which can be used as a metric for conveying the readiness of the healthcare institution.

To translate HLRI into an appropriate linguistic level for easy interpretation, we identified a linguistic label from the natural language expression set of the Healthcare Institution Lean Readiness (HLR). HLR set consists of five levels as shown in Figure 2. Several methods such as the Euclidean distance, successive approximation, and piecewise decomposition have been proposed in the literature for matching the membership function with linguistic terms. For this research, we used the Euclidean distance method as it is the most intuitive method for perceiving proximity (Lin et al. 2006). Assuming the natural-language Healthcare Institution Lean Readiness level expression set to be HLR, U_{HLRI} and U_{HLRi} represent the membership functions of the HLRI and of the natural-language Healthcare Institution Lean Readiness 'i', respectively. We calculated the distance between U_{HLRI} and U_{HLRi} as

$$d\ (\mathrm{HLRI}, \mathrm{HLR}_i) = \{\sum_{x \in p} \left(U_{HLRI}(x) - U_{HLR_i}(x)\right)^2\}^{1/2} \quad (4)$$

where $p=\{x_0, x_1, \ldots\ldots, x_m\}$ C [0, 1] so that $0 = x_0 < x_1 < \ldots. < x_m = 1.0$

"Insert Figure 2 here"

The distance between the HLRI and natural-language HLR *i* is then calculated and the closest natural expression with the smallest distance between U_{HLRI} to U_{HLRi} is identified. Using eq. 4, we calculated the Euclidean distance'd' between HLRI and each member in the set HLR:

D (HLRI, Not Ready) = 7.116

D (HLRI, Low Ready) = 4.985

D (HLRI, Average Ready) = 1.968

D (HLRI, Close to Ready) = 2.626

D (HLRI, Ready) = 4.553

From Figure 3, it can be clearly inferred that the equivalent linguistic label that is close to the primary care clinic's lean readiness level is *"Average Ready"*.

"Insert Figure 3 here"

4.3. Ranking using similarity to ideal solution technique

The technique for order of preference by similarity to ideal solution (TOPSIS) works such that the chosen alternative has the minimum distance from the positive ideal solution which maximizes the benefit criteria and minimizes the cost criteria, and has the maximum distance from the negative ideal solution which maximizes the cost criteria and minimizes the benefit criteria (Wang and Elhag, 2006; Wang and Lee, 2008; Mittal and Sangwan, 2015). Triantaphyllou and Lin (1996) developed a fuzzy version of the TOPSIS method that leads to a fuzzy relative closeness for each element. TOPSIS is a practitioner-friendly technique for ranking elements through measuring Euclidean distances.

We used the fuzzy readiness level obtained for all the elements and sub-elements of lean readiness framework for computing fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS). Using equations (5) and (6), we computed FPIS and FNIS of the sub-elements given in Table 12 respectively:

$$A^* = (v_1^*, v_2^*, \ldots, v_n^*) \qquad (5)$$

Where $v_j^* = \max_i \{v_{ij3}\}$, i=1, 2,…, m; j=1, 2,…, n.

$$A^- = (v_1^-, v_2^-, \ldots, v_n^-) \qquad (6)$$

Where $v_j^- = \min_i \{v_{ij3}\}$, i=1, 2,…, m; j=1, 2,…, n.

The distance (d_i^*, d_i^-) of fuzzy readiness value of each sub-element i=1, 2,…, m from the FPIS and the FNIS is computed using equation 4 as shown in Table 12. The closeness coefficient (CC_i) represents the distances to the FPIS (A^*) and the FNIS (A^-) simultaneously. The CC_i of each sub-element is calculated using Equation (7):

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, i = 1,2 \ldots m \qquad (7)$$

The closeness coefficients for sub-elements are given in Table 12. We adopted similar procedure to rank separately the sub-elements within each element (Table 13) and rank the six elements (Table 14).

"Insert Table 12 to Table 14 here"

5. Results

As a result of the assessment, we ranked the stakeholders along with its sub-elements in the proposed lean readiness framework depending on their level of readiness. Results of this readiness assessment provided several insights for the lean sensei and team about the healthcare unit and highlighted the weak areas that needed to be focused on before beginning the implementation of lean. The primary care clinic we assessed in this study is *"Average Ready"* for beginning the lean journey with an HLRI value of 5.75. On improving the weak elements and sub-elements of the lean readiness framework, the primary care clinic is expected to move to the "*Close to Ready*" category and potentially reach the "*Ready*" category with maximum feasible HLRI value.

5.1. Ranking of readiness sub-elements across all stakeholders

In Figure 4, we plot the CC_i of all the sub-elements put together in an increasing order to reveal the areas of focus for improving the readiness of the case organization across all stakeholders. We applied a Pareto principle to identify the critically weak areas (20% of least ranked elements) that need to be focused on for improving the readiness of the case organization. To identify the strong areas where the assessed healthcare unit

was doing much better, we used the same Pareto principle (20% of top ranked elements). Six strong and weak sub-elements were identified as listed in Table 15.

"Insert Figure 4 here"

"Insert Table 15 here"

5.2. Ranking of readiness sub-elements within a stakeholder group

In Figure 5, we plot the CC_i of the sub-elements under each element in an increasing order to reveal the areas of focus within an element for improving the readiness of individual stakeholders of the assessed healthcare unit and in turn increase the readiness of the entire unit. We used the Pareto principle to identify the weak areas that need to be focused on by each stakeholder to improve the readiness of the primary care clinic and also to identify the strong areas of each stakeholder. The sub-elements within a stakeholder group whose closeness coefficients are below and above the set threshold are listed in Table 16.

"Insert Figure 5 here"

"Insert Table 16 here"

5.3. Ranking of stakeholders

In Figure 6, we plot the CC_i of the stakeholders in an increasing order. This plot provides us with insights on the stakeholders who need to be focused for improving the lean readiness of the primary care unit. We applied the Pareto principle to identify the weakly ready and strongly ready stakeholders and listed them in Table 17.

"Insert Figure 6 here"

"Insert Table 17 here"

6. Discussion

6.1. Triangulating the readiness level of the case organization

Our current study adopts a case study methodology. Consequently, we qualitatively triangulate the quantitative results obtained from the assessment to establish the rigor of the procedure adopted and robustness of the results obtained (Jick, 1979; Eisenhardt, 1989). Our results of the readiness assessment showed that *Leadership and Executive Team* (LRF 1) in the case organization is "Average Ready" with strong *job security* policies (LRF 1.6) and *lean positions instituted* (LRF 1.4). The top management has to work on embracing a *systems approach* mindset (LRF 1.3) in all the other stakeholders of the healthcare unit. A systems approach can be embraced by listening to the opinions of stakeholders from all levels. This requires, for example, a revision of the healthcare unit's organization structure with respect to an *organic and open culture* (LRF 1.2). Changes implemented in such a restructuring have to be communicated to all the stakeholders of the healthcare unit. Subsequent to the communication of restructuring initiatives, the top management has to initiate trainings on *lean knowhow* (LRF 1.5) for all the stakeholders to guide them in understanding how this newly obtained autonomy can be put into effective use.

Similarly, the *Frontline Management Team* (LRF 2) is "Average Ready" with a strong *respect for peers and subordinates* (LRF 2.5) and complete *involvement and engagement of physician, nurse, and staff* (LRF 2.7). The frontline management team has to work on improving its *knowledge of existing systems* (LRF 2.2) such as process pathway, processes that need to be completed by patients and frontline management team before entry and exit of patients to the healthcare unit, etc. The frontline management team has to receive *customized hands-on training* (LRF 2.1) from the team of the lean sensei to overcome their *resistance to change* (LRF 2.6). To address the customized hands-on training requirement, the lean sensei and team had started a "*lean readiness laboratory*". As a result of the training and better understanding of the existing systems, the frontline management team's *multi-skill abilities* (LRF 2.3) are expected to improve.

The Lean sensei and team (LRF 3) is also "Average Ready" at the assessed healthcare unit. This can be attributed to the regular guidance of two lean experts who directly reported to the lean sensei of the healthcare group. The *expertise of the sensei and team* (LRF 3.1) at the assessed healthcare unit was maintained strong. The team was planning to use this clinic as a laboratory for the employees within the healthcare group where they can experience and learn about becoming ready before beginning the lean journey. Lean sensei and team have to work on improving the *comfort of frontline management team towards the lean team* (LRF 3.3). To achieve this, the lean sensei and team were planning to get onboard a proactive frontline management team member from the assessed healthcare unit who can motivate and set up a climate of encouragement for the lean journey implementation. In addition, it can establish a structured workforce planning to facilitate in changing employee's role and rotation of employees across teams or functions. The lean sensei and team have to focus on developing a detailed lean journey roadmap (LRF 3.2) for the assessed healthcare unit which has to be communicated to all the stakeholders of the unit.

In the case of *Patients and other customer groups* (LRF 4), the readiness level is "Low Ready". The strong sub-element is the respect, involvement and engagement of patients (LRF 4.2). Assessed healthcare unit has to improve the *knowledge of its patients on "end to end" process pathway* (LRF 4.3) from entry to exit. By consulting with lean sensei and team, frontline management team of the assessed healthcare unit can develop and display charts explaining the "end to end" process pathway of patients depending on the care required.

The primary care clinic has to focus on improving its "Not Ready" *supplier groups* (LRF 5) and "Low Ready" *healthcare institution attributes* (LRF 6). Key suppliers of the assessed healthcare unit have to be identified, informed, and involved in improving the readiness before beginning the lean journey. *Collaboration with few key suppliers* (LRF 5.1) such as the consumable suppliers, pharmacy companies, and equipment suppliers can be established to create long-term relationship and trust. The executive responsible for purchasing function has to discuss with the identified key suppliers to further improve its existing *service quality system with measurable metrics* (LRF 5.3). *Attributes of the healthcare unit* (LRF 6) has to be revisited for ensuring that all the prerequisites required for any change management are in place. The assessed healthcare unit is doing well on its *patient and employee safety policies* (LRF 6.4) which can be anchored upon for reducing the resistance to change among the frontline management team. The healthcare unit has to work on improving its *capacity and demand matching efforts* (LRF 6.2) by using the past data collected from the existing systems.

The triangulation performed is also expected to assist practitioners in understanding how to interpret the results obtained from readiness assessment.

6.2. Lean readiness laboratory

To address the areas of improvements identified in the case organization, the lean sensei and team had decided to initiate a *"Lean Readiness Laboratory"*. The objective of this "*Lean Readiness Laboratory*" was to convey the weak areas of readiness to the stakeholders of the healthcare unit by practically pilot testing small process improvement initiatives that are limited in scope but run deep in mindsets. Extreme attention was paid to the micro-details of the small process improvement initiatives implemented during pilot testing. The details were reflected upon at the end of the day to list the challenges faced and understand it from the lens of weak readiness areas as identified through the assessment. This laboratory was used as an environment for helping the people to learn and to facilitate the creation of engaged teams with knowledge on lean (Radnor, 2010; Radnor, 2011). The *Lean Readiness Laboratory* created the excitement within teams to fundamentally change the way they work. This *Laboratory* also laid the groundwork for other healthcare institutions within the healthcare group to solve their business problems by adopting or adapting the lean philosophy. The lean sensei and team decided that the *Lean Readiness Laboratory* had to be created with the following three characteristics:

- *Leadership:* leaders of the laboratory have to demonstrate passion for change and ability to build a sense of community and engagement around the improvement work
- *Place:* laboratory must be able to host locally the project team and the planning tools (wall space and working sessions)
- *Visibility:* laboratory must have high visibility in the healthcare unit (improvements made should be easy to notice)

The lean sensei and team expected that the learnings obtained by the stakeholders of the clinic using the *Lean Readiness Laboratory* would help them in a smooth transition towards implementing lean for optimizing the eight flows of healthcare: flow of patients, staff, families and visitors, information, medications, supplies, equipment and process engineering. Preparing for lean readiness can help the healthcare unit in stabilizing before defining, testing and implementing the most appropriate care delivery model (Jones et al., 2005). It also ensures that the

healthcare unit has the conducive culture profile for succeeding in lean implementation by matching the patient and organizational expectations (e.g. acting with humane orientation by always putting the patient first, nurturing trust and confidence to achieve high collectivism, lower level of assertiveness and finding joy in what they do, etc.) (Bortolotti et al., 2015).

6.3. Research implications, limitations and future directions

By proposing a framework with six stakeholder groups and associated sub-elements of lean readiness, we do not suggest that these factors are exhaustive. The parsimonious model proposed using stakeholder theory only includes the relevant readiness factors that are specific enough to capture core features and broad enough to capture the range of the lean phenomenon. Even though the readiness factors in this study were identified from an indepth literature review and were validated in a case organization, other factors unique to healthcare institution's context might still be present. This trade off is an inbuilt limitation for any parsimonious and generalizable (abstracted) framework (Eisenhardt, 1989).

Proposed framework overlooks the impact of external forces such as level of competition in the market, lean status of competitors, regulatory requirements, demand for healthcare services in the market, etc. For instance, healthcare institutions in a market with low competition would be much behind in its readiness level in comparison to those operating in high competing market. Readiness factors that are seen as a basic order qualifier in a high competing market could be seen as an order winner in a low competing market. Internal factors such as healthcare institution's size, ownership, affiliation, accreditation, etc. would also impact the readiness for lean implementation. Future empirical studies can conduct a cross-sectional survey to understand the relationship between these internal and external characteristics of healthcare institution and its readiness level (Jones et al. 2005), which can be operationalized as the readiness score computed using the assessment method proposed in this

study. On confirming a significant impact through our analysis, these factors have to be controlled in future empirical models dealing with readiness for lean implementation.

Stakeholders of a firm depend on both the firm and its other stakeholders to achieve their own objectives. Stakeholder interests are inseparably connected in a system of value creation in which each stakeholder provides resources or influence in exchange for some combination of tangible and/or intangible goods (Sachs & Rühli, 2011). Experience of several firms have showed that stakeholders have enough overlapping interests to make them function integratively in generating value to become better off over time (Freeman et al. 2007; Harrison and Wicks, 2013). According to Harrison and Wicks (2013), neglect of any one stakeholder could set off a downward spiral in the system as the firm's other stakeholders respond to what they observe. This dependence across stakeholders can be expected to have significant influence on the readiness of stakeholders. Future research should seek to examine how readiness of one particular stakeholder influences the readiness of another stakeholder. Future researchers can also investigate the impact of conflicting or cooperating relationship between stakeholders on their individual readiness as well as the overall readiness of the organization. This investigation will call for devising strategies to impart readiness among stakeholders depending on their relationship - cooperate or conflict.

As we use a single case study methodology, the findings of this study may not be entirely generalized in the healthcare sector. But the readiness framework developed is theoretically generalizable and can be directly applied to a different unit of assessment such as emergency units, cardiac, pharmacy, etc. within a healthcare institution. However, the assessors have to ensure that the operationalization of the readiness framework is done for the particular unit through the involvement of the directly affected stakeholder groups. For instance, if the unit of readiness assessment

is an emergency department (ED), then the physician, nurse, and staff working for that particular ED (frontline management team) have to be focused on for collecting the data.

As this study only reports the readiness assessment of a single healthcare institution at a particular point in time, future studies can also extend the proposed framework by conducting a longitudinal readiness assessment study within a single healthcare institution or by conducting a comparative study across different healthcare institutions. This would provide insights on how the proposed assessment technique compares and contrasts different healthcare institutions or a single healthcare institution at different points in time on their readiness level.

The motivation for this study is drawn from theoretical arguments and anecdotal evidences that emphasize the need for readiness to succeed in the implementation of lean in a healthcare institution. Future research could test empirical models linking readiness to lean implementation through quantitative surveys. This would help in generalizing the impact of readiness (if any) on the outcome of lean implementation by answering the question "how differently healthcare institutions at varying readiness level perform in their future lean implementation journey".

Even though the proposed assessment methodology overcomes the stated limitations of other assessment techniques, it adds complexity to the procedure of readiness assessment. Assessors interested in only using the stakeholder-based lean readiness framework in their assessment can treat Table 4 as a simple checklist for conducting their assessment. Every healthcare institution is unique and has its own strengths and weaknesses. Acknowledging these and accordingly adapting the lean philosophy to suit the healthcare institution's context can also be considered as part of the readiness initiative. Future research can take this up as an extension of this study to broadly group the hospitals into different categories and propose directions for the adaptation of lean philosophy.

The line where pre-implementation stops and lean implementation starts could be blurred in practice. The understanding and operationalization of lean readiness construct can vary between healthcare institutions. We acknowledge this limitation in deploying lean readiness assessment. However, healthcare institutions can overcome it by being consistent in its readiness operationalization throughout the lean journey. For instance, in this study, we operationalized readiness as any preparation that can be done before the actual lean implementation for re-engineering/improvement. The actual lean implementation starts when the healthcare institution begins to directly attack the inefficiencies and wastes in a value stream by following the five tenets of lean (Womack and Jones, 2009). This understanding is expected to help in demarcating readiness (pre-implementation) and implementation stage.

6.4. Practice implications

The stakeholder-based perspective for evaluating the readiness of a firm for implementing lean can help managers to determine where their attention is needed in order to facilitate the roll out of lean projects (Harrison and Wicks, 2013). Stakeholder-based lean readiness framework can assist practitioners in ensuring that all the prerequisites are in place before kick starting the lean implementation journey (Radnor, 2011; Gurumurthy et al., 2013; Al-Balushi et al., 2014; Garza-Reyes et al., 2015). The proposed lean readiness framework and its demonstrated assessment method are capable of identifying the strengths and weaknesses of a healthcare institution that needs to be acknowledged and addressed before beginning a lean transformation. Using the proposed assessment methodology, a stakeholder's readiness for lean implementation can be improved which in turn has been proven to increase the firm performance (Choi & Wang, 2009; Freeman et al., 2010) and operational performance (Yang et al., 2011; Khanchanapong et al., 2014; Qi et al., 2017).

Our proposed lean readiness framework can also be directly used as a checklist to conduct a simple, qualitative assessment if the assessors are comfortable with overlooking the subjectivity and impreciseness of the responses expected to be received. However, as the adoption and implementation of lean is a strategic decision, it is recommended to control for the impreciseness of the responses received. The chances of top management getting mislead by the binary (0 or 1) as well as absolute responses (1-5) gathered through checklist/instrument is very high as it fails to take into consideration the concept of partial truth, where the truth value can vary from "fully ready" to "not ready". Therefore, we believe that the proposed fuzzy logic based assessment methodology will deliver more robust result in comparison to a checklist based assessment.

The *lean readiness laboratory* described is also expected to provide guidelines for other healthcare institutions interested in imitating it. Stakeholder-based lean readiness framework helps in accounting the stakeholders for the level of readiness attained by the healthcare institution. Practitioners have to conceptualize healthcare institution readiness as a continuum rather than a binary measure (ready or not ready). As the proposed readiness assessment procedure delivers a single numeric continuous metric representing the overall readiness of the healthcare institution, practitioners can use this metric to perform readiness benchmarking with self or with others.

A detailed explanation of the procedures of the assessment along with the complete readiness instrument developed can assist healthcare practitioners in easily conducting the readiness assessment. The proposed assessment methodology has been kept simple to make it easier for deployment at the case organization and to make it acceptable by practitioners. The step-by-step description of the methodology is also expected to ensure the pursuit of readiness assessment. The computations involved can also be automated into a user-friendly platform in future such that it just takes numerical inputs from the assessors to deliver the status of readiness of different stakeholders and associated sub-elements. We expect

the lean readiness assessment methodology proposed and demonstrated in this study to significantly reduce the huge failure rates of lean implementation in healthcare institutions (Thelen, 2016).

7. Conclusion

By conducting a detailed literature review of case studies describing the implementation of lean projects in healthcare institutions, we identified the readiness factors for beginning the lean journey in a healthcare institution. This addressed the first research objective of this study. We used stakeholder theory to understand the readiness factors identified as each factor's achievement were directly attributable to a stakeholder. Through this understanding of readiness factors, we grouped them into stakeholders (elements) and sub-elements within a stakeholder to form the stakeholder-based lean readiness framework. This addresses the second research objective of this study. Using the proposed fuzzy input based assessment method and similarity to ideal solution technique, we ranked the elements and sub-elements listed in the readiness framework at overall and stakeholder level for a primary care clinic in USA. We also ranked stakeholders based on the readiness scores obtained from the assessment method. Finally, based on these rankings, we computed a numeric index for the assessed healthcare unit and identified future focus areas to improve the readiness of the healthcare unit before beginning the lean journey. This addresses the third and fourth research objective of this study. On reviewing the results of the readiness assessment carried out in this study, lean sensei and team of the primary care clinic decided to begin an initiative in the name of *Lean Readiness Laboratory* for ensuring smooth transition during the process of implementing lean.

Our research provides with a new perspective of assessing the readiness of a healthcare institution before pursuing implementation of lean. Our study is unique in terms of developing a lean readiness framework and demonstrating a lean readiness assessment technique in the context of

healthcare institutions. Usage of fuzzy input based assessment method to assess the readiness of a service organization (i.e. healthcare institution) and similarity to ideal solution to rank the elements is also an unique attempt.

Acknowledgments

The first author is grateful to the *United States-India Educational Foundation* and to the *J. William Fulbright Scholarship Board* for supporting his research. We authors also thank all the employees of the case organization for supporting us in conducting this project. Finally, we are thankful to the anonymous reviewers, editor and numerous colleagues who provided valuable feedback on this research.

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Figures

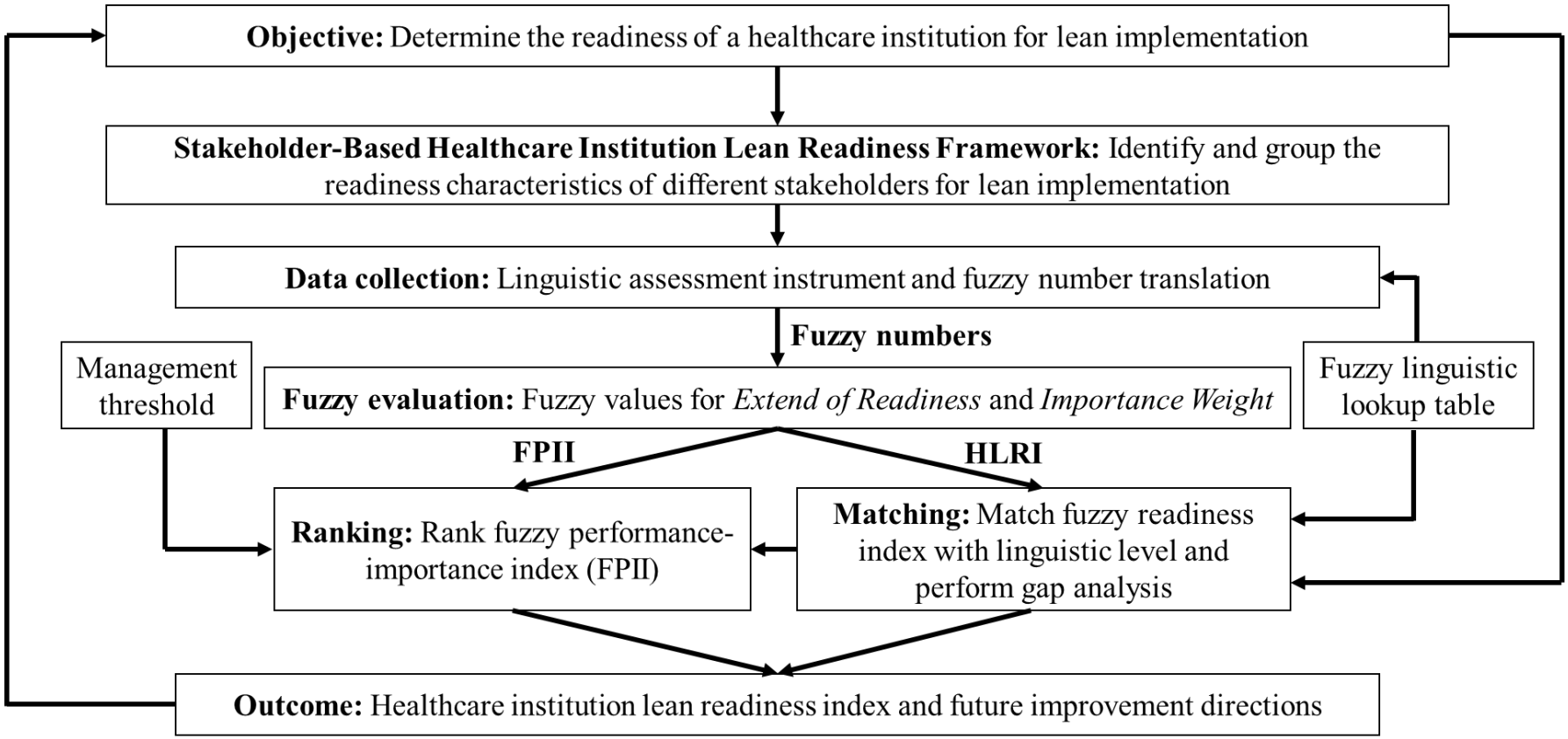

Figure 1 - Fuzzy Logic based healthcare institution lean readiness assessment procedure

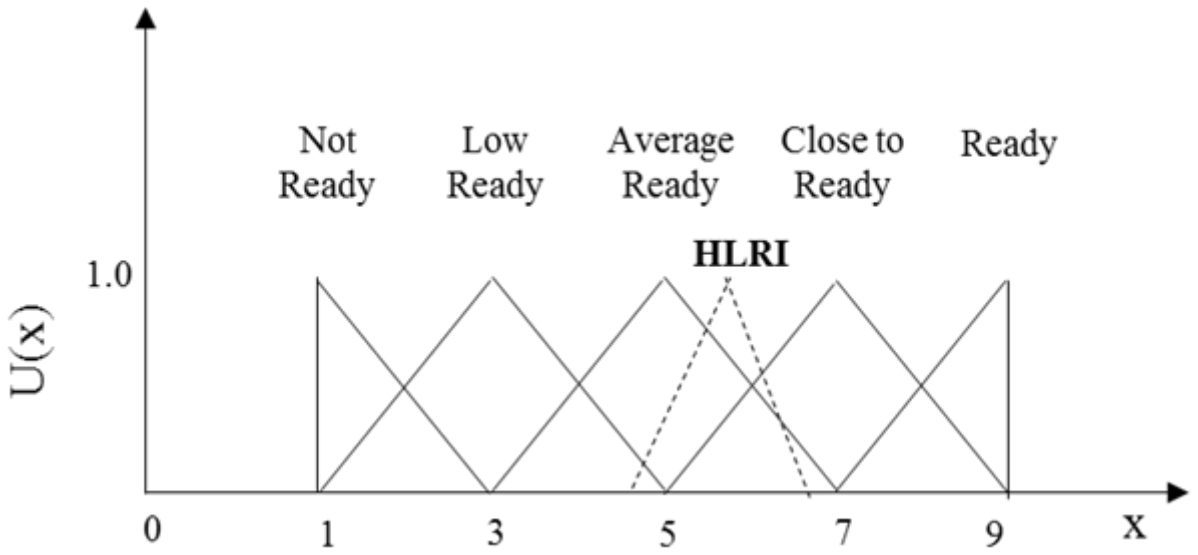

Figure 2 - Linguistic levels for matching HLRI

[HLR Member Set = {(Not Ready (1, 1, 3); Low Ready (1, 3, 5); Average Ready (3, 5, 7); Close to Ready (5, 7, 9); Ready (7, 9, 9)}]

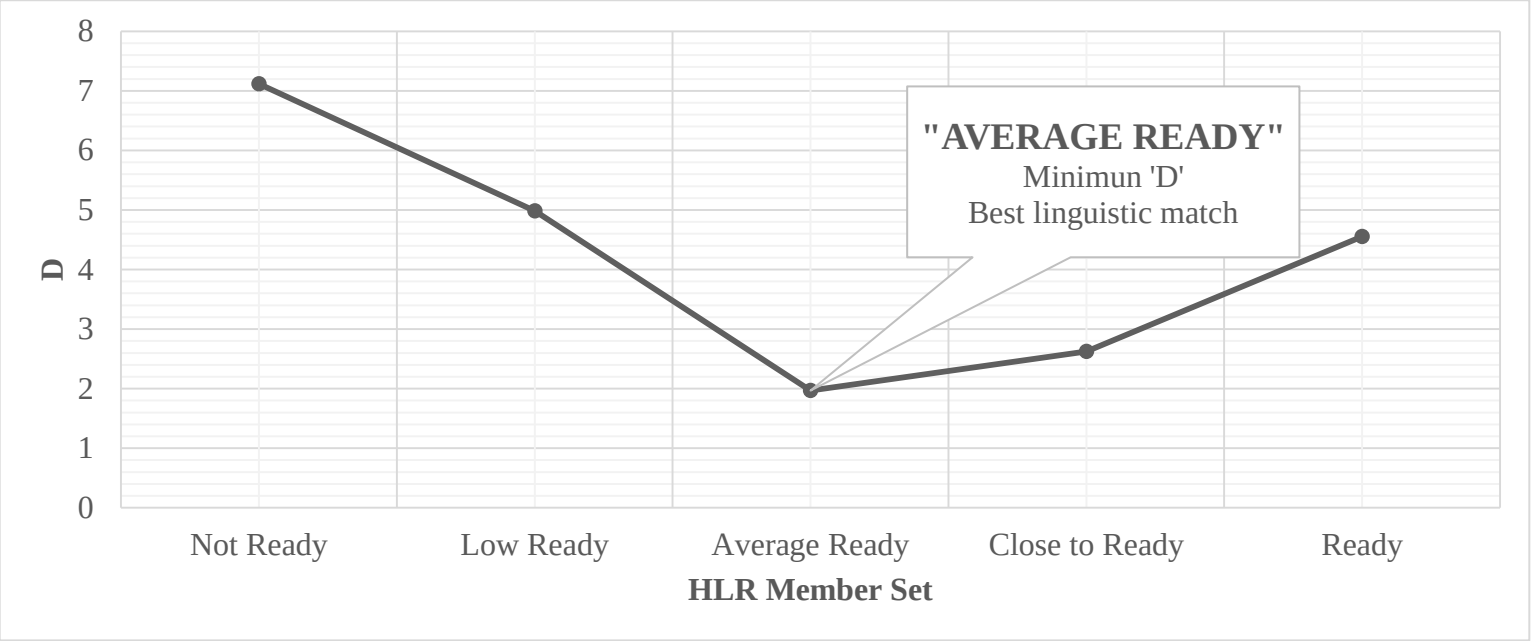

Figure 3 - HLRI Euclidean distance (D) from each member of HLR Set

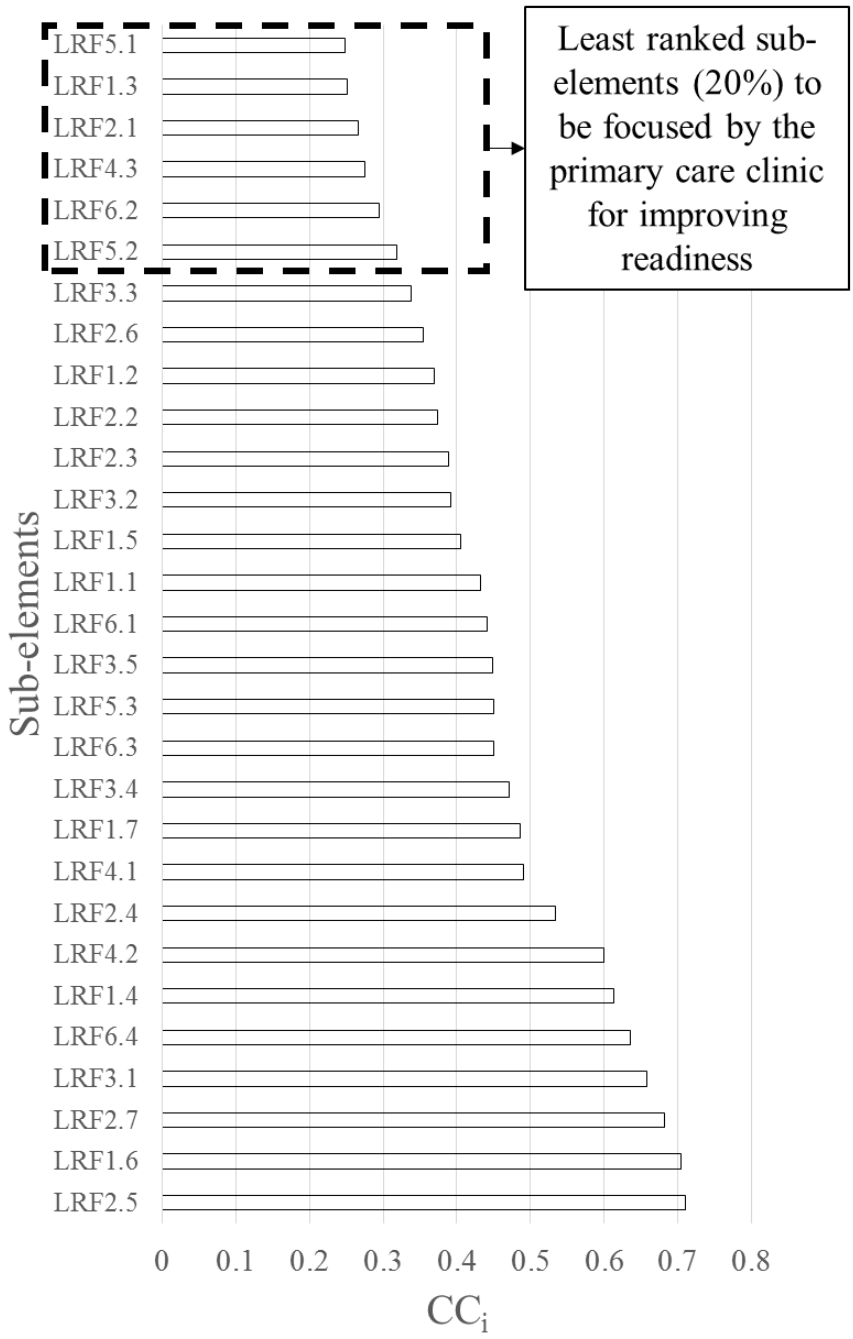

Figure 4 - Closeness coefficients of sub-elements and focus areas

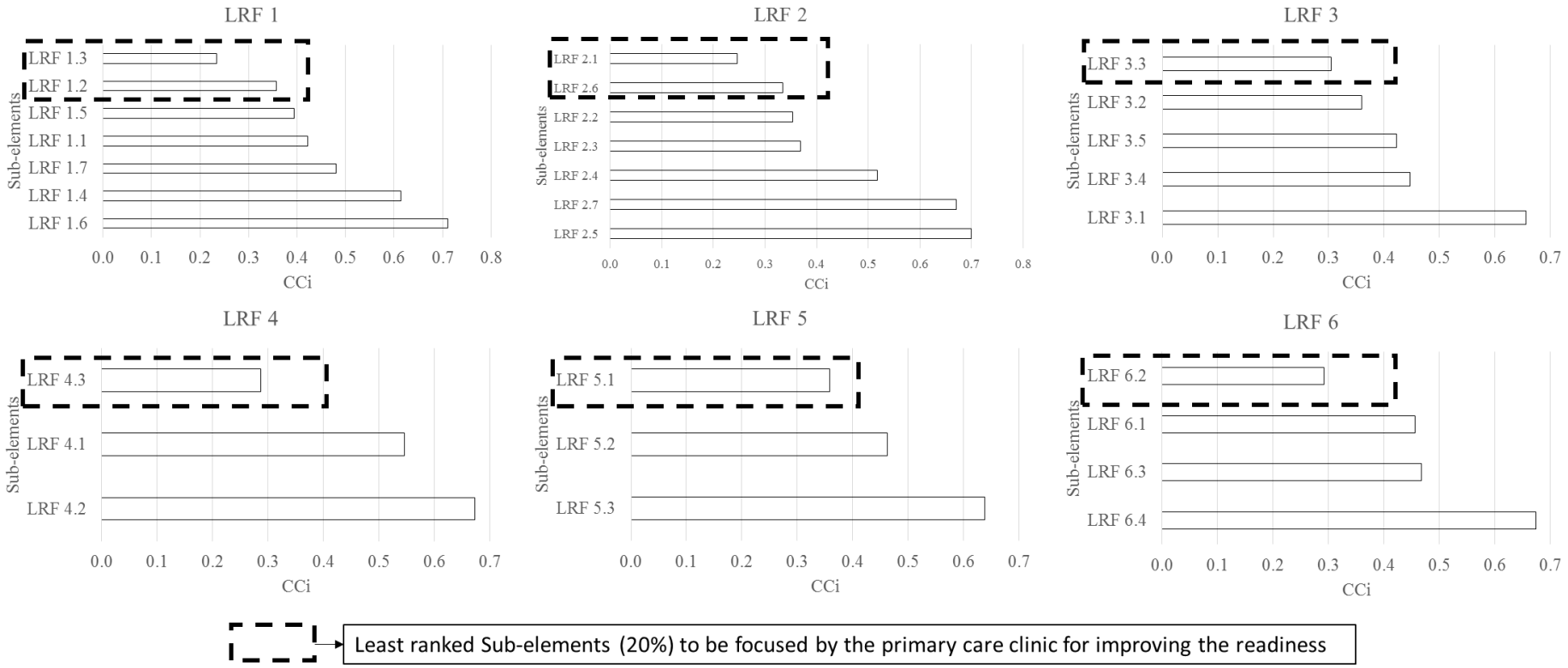

Figure 5 - Closeness coefficients of sub-elements and focus areas within an element

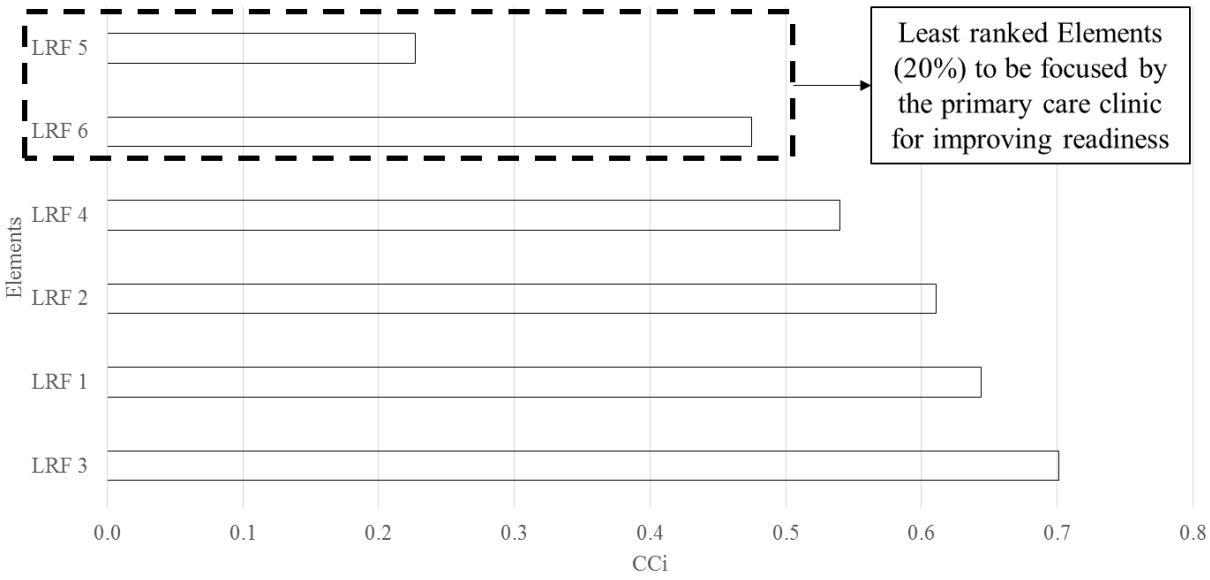

Figure 6 - Closeness coefficients of elements and focus areas

Tables

Table 1 - Snapshot of literature review on implementation of lean in healthcare institutions

Author	Year	Healthcare Institution Name	Research Question	Results
Bushell & Shelest	2002	Progressive Healthcare	How lean can help to improve primary care delivery processes?	Lean forces staff to stop and look at simple things that impact their daily work, find and address the issues, develop a team spirit, and give a feeling of control over their own lives.

Author	Year	Healthcare Institution Name	Research Question	Results
Jimmerson et al.	2005	Intermountain Health Care	Whether and how the principles of Toyota Production System (TPS) might apply to health care services?	The implementation of lean tools accelerated problem solving, facilitated communication and buy-in across departments.
King et al.	2006	Flinders Medical Centre, Adelaide, South Australia	How the concepts from Lean thinking can be applied to establish streams for patient flows in a teaching general hospital emergency department (ED)?	The total duration of the stay and waiting time for patients can be significantly reduced by streaming the flows. The streaming is carried out in relation to their predicted outcome.
Pham et al.	2007	Virginia Mason Medical Center	How to redesign care delivery to improve the performance while reducing costs?	Factors contributing to the success of Virginia Mason Production System (VMPS) were committed leadership to redesign care delivery, integrated system with an exclusively affiliated and salaried medical group, a cohesive culture, information technology to facilitate problem identification and implement change
Toussaint	2009	Theda Care ,Wisconsin	How lessons from lean manufacturing can help to improve care and lower costs in healthcare?	Improved care and reduced cost can be achieved through small cross-functional teams, collaborative care, patient's input, changing physician culture, and use of electronic health records
Chand	2011	Akron Children's Hospital	How to implement Lean Six Sigma Methodology to eliminate waste and variation in resident rounding?	The rounding process was studied to identify waste and the aspects of the activity that does not add value were found out
Radnor	2011	1.Pottery General Hospital NHS Trust, 2.Iron Hospital NHS Trust, 3.Ring Mental Health Trust	How organizations approach lean implementation? Do they focus only on tools of implementation and neglect organizational readiness?	There is a direct relationship between the approach taken, the conditions of readiness and the service improvement activity in the organization

Author	Year	Healthcare Institution Name	Research Question	Results
Díaz et al.	2012	Aravind Eye Care	How principles of early triage and Lean practices can be applied to provide better healthcare operations?	The main driver for Aravind's efficiency is an embedded set of lean services practices facilitated by an early triage process, and that a better understanding of these can bring improvements in the healthcare sector.
Garcia	2014	University of New Mexico	How Lean management principles can be used to improve patient satisfaction score and reduce wait time?	Using lean methodology and implementing PDSA (Plan, Do, Study, Act) cycle have significantly reduced procedure cycle time and improved patient satisfaction.

Table 2 - Snapshot of stakeholder based grouping of lean practices and performance measures implemented in healthcare institutions

Authors	Year	Practices	Performance Measures
Bushell & Shelest	2002	**Patients and other customer groups** - Self check-in by patients using smart cards for entry into exam room; **Lean Sensei and Team** - Value Stream Mapping, Standardized operations, Visual/audio controls; **Leadership & Executive Team -** Workplace organization, Information sharing;	**Healthcare institution attributes** - Patient waiting time, Distance travelled by nurse;
Jimmerson et al.	2005	**Healthcare institution attributes** - Eliminating schedule incongruities, Moving transcriptionists out of the work area to eliminate interruptions and clutter; **Patients and other customer groups** - Issue or problem is stated through the eyes of the customer; **Lean Sensei and Team** – VSM, 5 Whys method, Use of technology for real time information sharing, A3 problem solving approach, Aligning flow paperwork with flow of the specimens, **Leadership & Executive Team -**Relentlessly pursue for ideal state of error free work, Problems be taken in small and doable chunks, Consistent work processes;	**Healthcare institution attributes** - Backlog in pharmacy, Postage cost per year; **Patients and other customer groups** - Time to treatment; **Lean Sensei and Team** - Number of steps in getting order to pharmacy, Accuracy and time to billing;
King et al.	2006	**Patients and other customer groups** - Seeing patients in the order of arrival rather than to prioritize to triage category; **Lean Sensei and Team** - Value Stream Map (VSM), Segmenting or separating out care processes and managing each value stream separately, Continuous one piece flow;	**Patients and other customer groups** - Overall time spent by the patient in the department; Time spent by patient waiting for review; **Lean Sensei and Team** - Average number of patients in the ED at any time, Number of patients who do not wait;
Pham et al.	2007	**Healthcare institution attributes** - Identifying services that were not useful; **Patients and other customer groups** - Detailed review of individual cases;	**Healthcare institution attributes** - Costs per migraine episode, Imaging costs;

Authors	Year	Practices	Performance Measures
		Frontline Management Team - Feedback to individual physicians on cost performance; **Lean Sensei and Team** - Online order entry or preprinted order forms to automate restrictions on the number of pills on initial prescriptions and allow more pills on refills, Using published treatment guidelines;	
Toussaint	2009	**Frontline Management Team** - Small cross-functional teams; **Lean Sensei and Team** - Kaizen, VSM, Collaborative care, Standard work, PDSA **Healthcare institution attributes** - Locked and stocked medicine cabinets installed in each room (to give nurses extra time that could be spent at the bedside), Electronic health records;	**Healthcare institution attributes** - Defect free admission medication reconciliation, Preterm babies delivered, Mortality rate, Costs for a coronary bypass, Average cost per case; **Patients and other customer groups** - Same day appointments in every office, "Door-to-balloon" time (the minutes between a heart attack patient's entering a hospital and receiving a lifesaving angioplasty), Patient satisfaction, Case-mix-index; **Lean Sensei and Team** - Patients average time spent in hospital, Quality bundle compliance;
Chand	2011	**Patients and other customer groups** - Patient data recording in the online system; **Frontline Management Team** - Multidisciplinary team, Balance of workload, Coach residents and provide timely feedback on their physical examination, Receive adequate coaching and feedback from attendings, Autonomy to manage patients, Writing single collaborative note; **Lean Sensei and Team** - DMAIC, Value stream map (VSM), Continuous one-piece flow, Built-in quality, Standardized work;	**Patients and other customer groups** - Value-added time per patient, Total rounding time per patient, Time my physicians will take to see my child and me, Time taken to answer my questions each day, Length of stay; **Frontline Management Team** - Residents walking distance; **Lean Sensei and Team** - Number of adverse events;
Radnor	2011	**Healthcare institution attributes** - Effective monitoring of implementation, outcomes and impact, Freeing the time of key resources, Reduction of time between two departments;	**Healthcare institution attributes** - Direct savings; **Patients and other customer groups** - Recording patient details in multiple places, Patients being moved

Authors	Year	Practices	Performance Measures
		Frontline Management Team - Visible leadership, Dedicated lean project teams, Dedicated local lean experts based in local offices, Central lean experts rotated over three-month periods between sites supported by external consultants, Senior managers to 'Lead Lean', Relevant training of staff, Internal team to support the lean activity, Improvement seen as part of their role, Communication of the changes, Team working skills, More clarity around staff accountability, **Lean Sensei and Team** - Rapid Improvement Events (RIE's) or a Kaizen event, Process mapping, Demand-capacity matching	before beds are available, Length of stay, Number of patients being moved from one ward to another, Death rate for patients; **Frontline Management Team -** Excessive waiting for doctors and consultants, Staff walking distance, Manpower FTE; **Lean Sensei and Team -** Average turnaround time in pathology, Time taken to process important categories of blood, Number of infections, Number of non-safety incidents;
Díaz et al.	2012	**Healthcare institution attributes** - Pokayoke (use of colored saris and cards to identify patient sub-flows, use of simple brochures to prepare patients for process), Transport and motion reduction (compact size of facilities and optimization evident in design of operating theatre reduces motion waste), Waiting (streamlined processes facilitate reduction of bottlenecks); **Patients and other customer groups** - Use of software to assign patients to OPD (to balance flow between units), Registration of recurring patients directly at specialty clinic, **Lean Sensei and Team** - VSM, Variability reduction (triage performed at the field, and at the beginning of process facilitate the classification of patients and capture data), Process simplification; **Supplier groups** - Inventory optimization (vertical integration with maker of critical supplies used to reduce costs and assure availability of critical supplies);	Not mentioned
Garcia	2014	**Frontline Management Team** - Eliminate front staff involvement in procedure related questions and patients transportation; **Lean Sensei and Team** - PDSA, Scheduling changes;	**Patients and other customer groups** - Recovery cycle time; **Frontline Management Team** - Staff overtime;

Authors	Year	Practices	Performance Measures
			Lean Sensei and Team - Registration cycle time, Procedure cycle time;

Table 3 – Snapshot of implicitly stated lean readiness factors from the review of lean implementation in healthcare institutions literature

Author	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Bushell & Shelest	2002					☑					☑		☑	☑	☑		☑	☑	☑	☑		☑								☑	☑	
Jimmerson et al.	2005					☑					☑				☑					☑			☑		☑				☑		☑	☑
King et al.	2006			☑		☑				☑			☑							☑			☑			☑	☑	☑				
Pham et al.	2007			☑		☑					☑					☑				☑										☑		
Toussaint	2009					☑	☑		☑	☑			☑	☑		☑	☑		☑	☑		☑			☑		☑				☑	
Chand	2011			☑	☑	☑	☑			☑		☑		☑	☑	☑	☑	☑		☑			☑	☑					☑			☑
Radnor	2011			☑	☑	☑	☑				☑		☑	☑		☑	☑	☑	☑		☑		☑	☑	☑		☑			☑	☑	☑
Díaz et al.	2012			☑						☑	☑	☑			☑			☑	☑		☑		☑						☑			
Garcia	2014																					☑			☑				☑			

Implicitly Stated Lean Readiness Factors: 1 - Assessments of employee satisfaction; 2 - Barcode labelling for specimens; 3 - Capacity and demand matching efforts; 4 - Customized hands-on training; 5 - Data measurement system; 6 - Expertise of sensei and team; 7 - Instituting lean positions; 8 - Job security; 9 - Knowledge of customer groups; 10 - Knowledge of the existing systems; 11 - Lean journey roadmap; 12 - Comfort with lean team; 13 - Least resistance to change; 14 - Lean knowhow; 15 - Multi-skilled physicians, nurses, and staff; 16 - Organic structure & Open culture; 17 - Past change experiences; 18 - Patient and employee safety; 19 - Patient respect, involvement and engagement; 20 - Patient's knowledge of "end to end" process pathway; 21 - Physician, nurse, and staff involvement and engagement; 22 - Process-learning metrics; 23 - Respect for peers and sub-ordinates; 24 - Strategic agenda alignment; 25 - Supplier collaboration and partnership; 26 - Supplier involvement and alignment; 27 - Supplier Service quality; 28 - Systems approach; 29 - Team culture among physician, nurse, and staff; 30 - Top management commitment; 31 - Traveling together with a common objective.

Table 4 – Stakeholder-based lean readiness framework (LRF) for healthcare institutions

Healthcare Institution Lean Readiness Element (Stakeholder)	S. No.	Healthcare Institution Lean Readiness Sub-Element
LRF1. Leadership and Executive Team	LRF1.1	Strategic agenda alignment
	LRF1.2	Organic structure & Open culture
	LRF1.3	Systems approach
	LRF1.4	Instituting lean positions
	LRF1.5	Lean knowhow
	LRF1.6	Job security
	LRF1.7	Top management commitment
LRF2. Frontline Management Team	LRF2.1	Customized hands-on training
	LRF2.2	Knowledge of the existing systems
	LRF2.3	Multi-skilled physicians, nurses, and staff
	LRF2.4	Team culture among physician, nurse, and staff
	LRF2.5	Respect for peers and sub-ordinates
	LRF2.6	Least resistance to change
	LRF2.7	Physician, nurse, and staff involvement and engagement
LRF3. Lean Sensei and Team	LRF3.1	Expertise of sensei and team
	LRF3.2	Lean journey roadmap
	LRF3.3	Comfort with lean team
	LRF3.4	Traveling together attitude
	LRF3.5	Process-learning metrics
LRF4. Patients and Other Customer Groups	LRF4.1	Knowledge of customer groups
	LRF4.2	Patient respect, involvement and engagement
	LRF4.3	Patient's knowledge of "end to end" process pathway
LRF5. Supplier Groups	LRF5.1	Supplier collaboration and partnership
	LRF5.2	Supplier involvement and alignment
	LRF5.3	Supplier service quality
LRF6. Healthcare Institution Attributes	LRF6.1	Data measurement system
	LRF6.2	Capacity and demand matching efforts
	LRF6.3	Past change experiences
	LRF6.4	Patient and employee safety

Table 5 - Instrument for collecting data on healthcare institution's lean readiness framework elements

S. No.	Elements	Description & Response							
LRF1	**Leadership and Executive Team**	Healthcare unit needs to have high commitment and push from the top management to implement lean.							
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
LRF2	**Frontline Management Team**	Frontline management team in healthcare unit needs to satisfy certain prerequisites before implementing lean.							
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
LRF3	**Lean Sensei and Team**	Oversight expert committee to coordinate the lean journey between leadership and frontline employees. Adaptation of manufacturing lean concepts to healthcare and in specific to the healthcare institution.							
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
LRF4	**Patients and other customer groups**	Aspects related to customers, both internal and external, needs to be understood before proceeding with lean implementation.							
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
LRF5	**Supplier groups**	Supplier is key in implementing lean in the healthcare institution as they can have the capacity to increase or decrease waste in the focal organization.							
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
LRF6	**Healthcare institution attributes**	Healthcare institution characteristics which needs to be made favorable for lean implementation. This involves primarily fixed resource investment which is independent of lean implementation, but having them in place makes lean implementation much smoother and impactful.							
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory

Table 6 - Snapshot of instrument for collecting data on healthcare institution's lean readiness framework sub-elements

S. No.	Sub-Elements	Description & Response						
LRF1		**Leadership & Executive Team**						
LRF1.1	***Strategic agenda alignment***	Healthcare unit's leadership team has to develop strategic actions to revise and associate lean with current agenda and mission. It has to ensure common understanding on lean definition across the healthcare institution.						
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
		Extent of readiness	Not ready	Little ready	Somewhat ready	Fairly ready	Almost ready	Ready	Extremely ready
LRF1.2	***Organic structure & Open culture***	Healthcare organization's structure needs to have least power differentials to ensure inclusion, encourage innovation and sustain new work routines. Strong cohesive leadership by engaging both senior and middle managers needs to exist. Devolution of authority to the primarily nurse led teams has been initiated by leadership team to increase the degree of improvement. Culture to openly share the key successes and failures with all leaders and staff. Culture of moving from one of fire-fighting and responding immediately to one of cause and effect.						
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
		Extent of readiness	Not ready	Little ready	Somewhat ready	Fairly ready	Almost ready	Ready	Extremely ready
LRF1.3	***Systems approach***	Healthcare unit's leadership team takes a wider view of improvement by crossing the boundaries of functions and by breaking the departmental silos. Lean is not just considered as a technique for cost elimination. Understanding to not encourage adhoc problem-solutions that are not completely aligned with end-to-end Lean implementation. Changing mindset from measuring progress in terms of the absolutes of success or failure to consistently meeting expected outcomes.						
		Importance Weight	Not important	Least important	Somewhat important	Important	Extremely important	Absolutely critical	Mandatory
		Extent of readiness	Not ready	Little ready	Somewhat ready	Fairly ready	Almost ready	Ready	Extremely ready

Table 7 - Linguistic variables and their corresponding fuzzy numbers

Extent of Readiness				Importance weights			
Linguistic variable	**Fuzzy numbers**			**Linguistic variable**	**Fuzzy numbers**		
Not Ready [NR]	1	2	3	Not Important [NI]	0	0.05	0.15
Little Ready [LR]	2	3	4	Least Important [LI]	0.1	0.2	0.3
Somewhat Ready [SR]	3	4	5	Somewhat Important [SI]	0.2	0.35	0.5
Fairly Ready [FR]	4	5	6	Important [IT]	0.3	0.5	0.7
Almost Ready [AR]	5	6	7	Extremely Important [EI]	0.5	0.65	0.8
Ready [RY]	6	7	8	Absolutely Critical [AC]	0.7	0.8	0.9
Fully Ready [FR]	7	8	9	Mandatory [MY]	0.85	0.95	1

Table 8 - Snapshot of linguistic fuzzy values for *Extent of Readiness* and *Importance weights* of sub-elements under the tenet "LRF1".

Lean Readiness Framework Element (LRF_i)	**Lean Readiness Framework Sub-element (LRF_{ij})**	**Extent of Readiness**					**Importance Weight**				
		A1	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
							AC	AC	MY	MY	IT
LRF1	LRF1.1	FR	SR	AR	RY	FR	EI	EI	EI	AC	AC
	LRF1.2	AR	SR	SR	FR	SR	IT	AC	AC	EI	MY
	LRF1.3	RY	LR	LR	LR	FR	EI	AC	IT	EI	SI
	LRF1.4	FR	FR	FR	FR	FR	EI	EI	MY	AC	AC
	LRF1.5	FR	SR	AR	FR	LR	AC	AC	MY	AC	EI
	LRF1.6	RY	RY	AR	FR	RY	MY	EI	MY	MY	AC
	LRF1.7	RY	RY	AR	FR	FR	EI	EI	MY	EI	EI

Table 9 - Conversion of linguistic fuzzy values of *Extent of Readiness* and *Importance Weight* into fuzzy numbers for "LRF1.1".

Assessors	**Extent of Readiness**	**Equivalent Fuzzy Number**			**Importance Weight**	**Equivalent Fuzzy Number**		
A1	Fairly Ready [FR]	4	5	6	Extremely Important [EI]	0.5	0.65	0.8
A2	Somewhat Ready [SR]	3	4	5	Extremely Important [EI]	0.5	0.65	0.8
A3	Almost ready [AR]	5	6	7	Extremely Important [EI]	0.5	0.65	0.8
A4	Ready [RY]	6	7	8	Absolutely Critical [AC]	0.7	0.8	0.9
A5	Fairly Ready [FR]	4	5	6	Absolutely Critical [AC]	0.7	0.8	0.9
Fuzzy average *Extent of Readiness* of LRF1.1		**4.4**	**5.4**	**6.4**	**Fuzzy average Importance Weight of LRF1.1**	**0.58**	**0.71**	**0.84**

Table 10 - Readiness level and ranking scores of sub-elements of lean readiness framework

Sub-element	Average Extent of Readiness			Average Importance Weight			Readiness Level			Readiness Value
LRF1.1	4.40	5.40	6.40	0.58	0.71	0.84	2.55	3.83	5.38	3.92
LRF1.2	3.60	4.60	5.60	0.61	0.74	0.86	2.20	3.40	4.82	3.47
LRF1.3	3.20	4.20	5.20	0.44	0.59	0.74	1.41	2.48	3.85	2.58
LRF1.4	5.80	6.80	7.80	0.65	0.77	0.88	3.77	5.24	6.86	5.29
LRF1.5	3.60	4.60	5.60	0.69	0.80	0.90	2.48	3.68	5.04	3.73
LRF1.6	6.00	7.00	8.00	0.75	0.86	0.94	4.50	6.02	7.52	6.01
LRF1.7	5.00	6.00	7.00	0.57	0.71	0.84	2.85	4.26	5.88	4.33
LRF2.1	3.80	4.80	5.80	0.36	0.53	0.70	1.37	2.54	4.06	2.66
LRF2.2	5.00	6.00	7.00	0.40	0.56	0.72	2.00	3.36	5.04	3.47
LRF2.3	4.20	5.20	6.20	0.56	0.68	0.80	2.35	3.54	4.96	3.62
LRF2.4	5.80	6.80	7.80	0.55	0.68	0.80	3.19	4.62	6.24	4.68
LRF2.5	6.60	7.60	8.60	0.68	0.80	0.90	4.49	6.08	7.74	6.10
LRF2.6	4.20	5.20	6.20	0.46	0.62	0.78	1.93	3.22	4.84	3.33
LRF2.7	6.60	7.60	8.60	0.72	0.83	0.92	4.32	5.81	7.36	5.83
LRF3.1	4.40	5.40	6.40	0.61	0.74	0.86	4.03	5.62	7.40	5.68
LRF3.2	4.80	5.80	6.80	0.50	0.65	0.80	2.20	3.51	5.12	3.61
LRF3.3	4.60	5.60	6.60	0.36	0.53	0.70	1.73	3.07	4.76	3.19
LRF3.4	4.00	5.00	6.00	0.61	0.74	0.86	2.81	4.14	5.68	4.21
LRF3.5	4.80	5.80	6.80	0.69	0.80	0.90	2.76	4.00	5.40	4.05
LRF4.1	5.20	6.20	7.20	0.61	0.74	0.86	2.93	4.29	5.85	4.36
LRF4.2	4.00	5.00	6.00	0.72	0.83	0.92	3.74	5.15	6.62	5.17
LRF4.3	4.00	5.00	6.00	0.38	0.53	0.68	1.52	2.65	4.08	2.75
LRF5.1	3.40	4.40	5.40	0.28	0.47	0.66	1.12	2.35	3.96	2.48
LRF5.2	4.20	5.20	6.20	0.54	0.68	0.82	1.84	2.99	4.43	3.09
LRF5.3	5.00	6.00	7.00	0.65	0.77	0.88	2.73	4.00	5.46	4.06
LRF6.1	4.20	5.20	6.20	0.52	0.65	0.78	2.60	3.90	5.46	3.99
LRF6.2	4.40	5.40	6.40	0.36	0.53	0.7	1.51	2.76	4.34	2.87
LRF6.3	5.80	6.80	7.80	0.61	0.74	0.86	2.68	4.00	5.50	4.06
LRF6.4	3.80	4.80	5.80	0.68	0.8	0.9	3.94	5.44	7.02	5.47

Table 11 - Readiness level and ranking scores of elements of lean readiness framework

Element	Computed Extent of Readiness			Average Importance Weight			Readiness Level			Readiness Value
LRF1	4.61	5.58	6.56	0.68	0.80	0.90	3.13	4.47	5.90	4.50
LRF2	5.27	6.21	7.16	0.55	0.68	0.80	2.90	4.22	5.73	4.28

LRF3	4.88	5.88	6.88	0.72	0.83	0.92	3.51	4.88	6.33	4.91
LRF4	4.79	5.76	6.73	0.51	0.65	0.78	2.44	3.74	5.25	3.81
LRF5	3.87	4.87	5.87	0.20	0.35	0.50	0.77	1.70	2.93	1.80
LRF6	4.95	5.92	6.89	0.41	0.56	0.70	2.03	3.31	4.82	3.39
		HLRI					**4.797**	**5.744**	**6.703**	**5.75**

Table 12 - Distance, closeness coefficients, and ranking of sub-elements using similarity to ideal solution technique

Sub-element	Lean Readiness Level			D_FPIS (B+)	D_FPIS (B-)	CC_i	Rank
LRF1.1	2.552	3.834	5.376	3.99	3.03	0.43	16
LRF1.2	2.196	3.404	4.816	4.40	2.58	0.37	21
LRF1.3	1.408	2.478	3.848	5.26	1.77	0.25	28
LRF1.4	3.77	5.236	6.864	2.76	4.36	0.61	6
LRF1.5	2.484	3.68	5.04	4.14	2.82	0.40	17
LRF1.6	4.5	6.02	7.52	2.12	5.05	0.70	2
LRF1.7	2.85	4.26	5.88	3.63	3.44	0.49	10
LRF2.1	1.368	2.544	4.06	5.20	1.89	0.27	27
LRF2.2	2	3.36	5.04	4.45	2.66	0.37	20
LRF2.3	2.352	3.536	4.96	4.26	2.71	0.39	19
LRF2.4	3.19	4.624	6.24	3.30	3.78	0.53	8
LRF2.5	4.488	6.08	7.74	2.11	5.16	0.71	1
LRF2.6	1.932	3.224	4.836	4.57	2.51	0.35	22
LRF2.7	4.32	5.81	7.36	2.28	4.87	0.68	3
LRF3.1	4.026	5.624	7.396	2.48	4.77	0.66	4
LRF3.2	2.2	3.51	5.12	4.30	2.76	0.39	18
LRF3.3	1.728	3.074	4.76	4.72	2.41	0.34	23
LRF3.4	2.806	4.144	5.676	3.72	3.30	0.47	11
LRF3.5	2.76	4	5.4	3.84	3.13	0.45	14
LRF4.1	2.928	4.292	5.848	3.59	3.45	0.49	9
LRF4.2	3.744	5.146	6.624	2.83	4.22	0.60	7
LRF4.3	1.52	2.65	4.08	5.10	1.94	0.28	26
LRF5.1	1.12	2.35	3.96	5.39	1.79	0.25	29
LRF5.2	1.836	2.992	4.428	4.77	2.23	0.32	24
LRF5.3	2.73	4.004	5.456	3.84	3.15	0.45	13
LRF6.1	2.6	3.9	5.46	3.93	3.10	0.44	15
LRF6.2	1.512	2.756	4.34	5.01	2.10	0.30	25
LRF6.3	2.684	3.996	5.504	3.85	3.16	0.45	12
LRF6.4	3.944	5.44	7.02	2.60	4.53	0.64	5
FPIS (B+)	**7.74**	**7.74**	**7.74**				
FNIS (B-)	**1.12**	**1.12**	**1.12**				

Table 13 - Distance, closeness coefficients, and ranking of sub-elements within an element using similarity to ideal solution technique

Element	Sub-element	Lean Readiness Level			D_FPIS (B+)	D_FPIS (B-)	CC_i	Rank
LRF1	LRF 1.1	2.552	3.834	5.376	3.78	2.77	0.42	4
	LRF 1.2	2.196	3.404	4.816	4.19	2.33	0.36	6
	LRF 1.3	1.408	2.478	3.848	5.04	1.54	0.23	7
	LRF 1.4	3.77	5.236	6.864	2.56	4.08	0.61	2
	LRF 1.5	2.484	3.68	5.04	3.93	2.55	0.39	5
	LRF 1.6	4.5	6.02	7.52	1.95	4.77	0.71	1
	LRF 1.7	2.85	4.26	5.88	3.42	3.17	0.48	3
	FPIS (B+)	7.52	7.52	7.52				
	FNIS (B-)	1.408	1.408	1.408				
LRF2	LRF 2.1	1.368	2.544	4.06	5.20	1.70	0.25	7
	LRF 2.2	2	3.36	5.04	4.45	2.44	0.35	5
	LRF 2.3	2.352	3.536	4.96	4.26	2.49	0.37	4
	LRF 2.4	3.19	4.624	6.24	3.30	3.54	0.52	3
	LRF 2.5	4.488	6.08	7.74	2.11	4.92	0.70	1
	LRF 2.6	1.932	3.224	4.836	4.57	2.29	0.33	6
	LRF 2.7	4.32	5.81	7.36	2.28	4.63	0.67	2
	FPIS (B+)	7.74	7.74	7.74				
	FNIS (B-)	1.368	1.368	1.368				
LRF3	LRF 3.1	4.026	5.624	7.396	2.20	4.19	0.66	1
	LRF 3.2	2.2	3.51	5.12	3.97	2.23	0.36	4
	LRF 3.3	1.728	3.074	4.76	4.39	1.92	0.30	5
	LRF 3.4	2.806	4.144	5.676	3.40	2.74	0.45	2
	LRF 3.5	2.76	4	5.4	3.51	2.56	0.42	3
	FPIS (B+)	7.396	7.396	7.396				
	FNIS (B-)	1.728	1.728	1.728				
LRF4	LRF 4.1	2.928	4.292	5.848	2.56	3.08	0.55	2
	LRF 4.2	3.744	5.146	6.624	1.87	3.84	0.67	1
	LRF 4.3	1.52	2.65	4.08	4.01	1.62	0.29	3
	FPIS (B+)	6.624	6.624	6.624				
	FNIS (B-)	1.52	1.52	1.52				
LRF5	LRF 5.1	1.12	2.35	3.96	3.20	1.79	0.36	3
	LRF 5.2	1.836	2.992	4.428	2.60	2.23	0.46	2
	LRF 5.3	2.73	4.004	5.456	1.78	3.15	0.64	1
	FPIS (B+)	5.456	5.456	5.456				
	FNIS (B-)	1.12	1.12	1.12				
LRF6	LRF 6.1	2.6	3.9	5.46	3.25	2.74	0.46	3
	LRF 6.2	1.512	2.756	4.34	4.31	1.78	0.29	4
	LRF 6.3	2.684	3.996	5.504	3.18	2.80	0.47	2
	LRF 6.4	3.944	5.44	7.02	2.00	4.15	0.68	1
	FPIS (B+)	7.02	7.02	7.02				

FNIS (B-)	1.512	1.512	1.512

Table 14 - Distance, closeness coefficients, and ranking of elements using similarity to ideal solution technique

Element	Lean Readiness Level			D_FPIS (B+)	D_FPIS (B-)	CC_i	Rank
LRF 1	3.13212	4.46517	5.90160	2.15	3.89	0.64400878	2
LRF 2	2.89745	4.22150	5.72754	2.35	3.69	0.61093441	3
LRF 3	3.51422	4.88213	6.33103	1.83	4.29	0.70123659	1
LRF 4	2.44323	3.74152	5.24820	2.77	3.25	0.53973331	4
LRF 5	0.77361	1.70370	2.93305	4.61	1.36	0.22735999	6
LRF 6	2.02922	3.31306	4.82309	3.16	2.85	0.47478497	5
FPIS (B+)	7.52	7.52	7.52				
FNIS (B-)	1.408	1.408	1.408				

Table 15 - Strong and weak Sub-elements of lean readiness framework in the assessed healthcare unit

Strong Sub-elements	
LRF2.5	Respect for peers and sub-ordinates
LRF1.6	Job security
LRF2.7	Physician, nurse, and staff involvement and engagement
LRF3.1	Expertise and experience of sensei and team
LRF6.4	Patient and employee safety
LRF1.4	Instituting lean positions
Weak Sub-elements	
LRF5.1	Supplier collaboration and partnership
LRF1.3	Systems approach
LRF2.1	Customized hands-on training
LRF4.3	Patient’s knowledge of “end to end” process pathway
LRF6.2	Capacity and demand matching efforts
LRF5.2	Supplier involvement and alignment

Table 16 - Strong and weak sub-elements within an element of lean readiness framework in the assessed healthcare unit

Element	Strong Sub-elements		Weak Sub-elements	
LRF 1	LRF 1.6	Job security	LRF 1.3	Systems approach
	LRF 1.4	Instituting lean positions	LRF 1.2	Organic structure & Open culture
LRF 2	LRF 2.5	Respect for peers and sub-ordinates	LRF 2.1	Customized hands-on training
	LRF 2.7	Physician, nurse, and staff involvement and engagement	LRF 2.6	Least resistance to change
LRF 3	LRF 3.1	Expertise of sensei and team	LRF 3.3	Comfort with lean team
LRF 4	LRF 4.2	Patient respect, involvement and engagement	LRF 4.3	Patient's knowledge of "end to end" process pathway
LRF 5	LRF 5.3	Supplier service quality	LRF 5.1	Supplier collaboration and partnership
LRF 6	LRF 6.4	Patient and employee safety	LRF 6.2	Capacity and demand matching efforts

Table 17 - Strong and weak elements of lean readiness framework in the assessed healthcare unit

Strong Elements		Weak Elements	
LRF 3	Lean Sensei and Team	LRF 5	Supplier Groups
LRF 1	Leadership & Executive Team	LRF 6	Healthcare Institution Attributes